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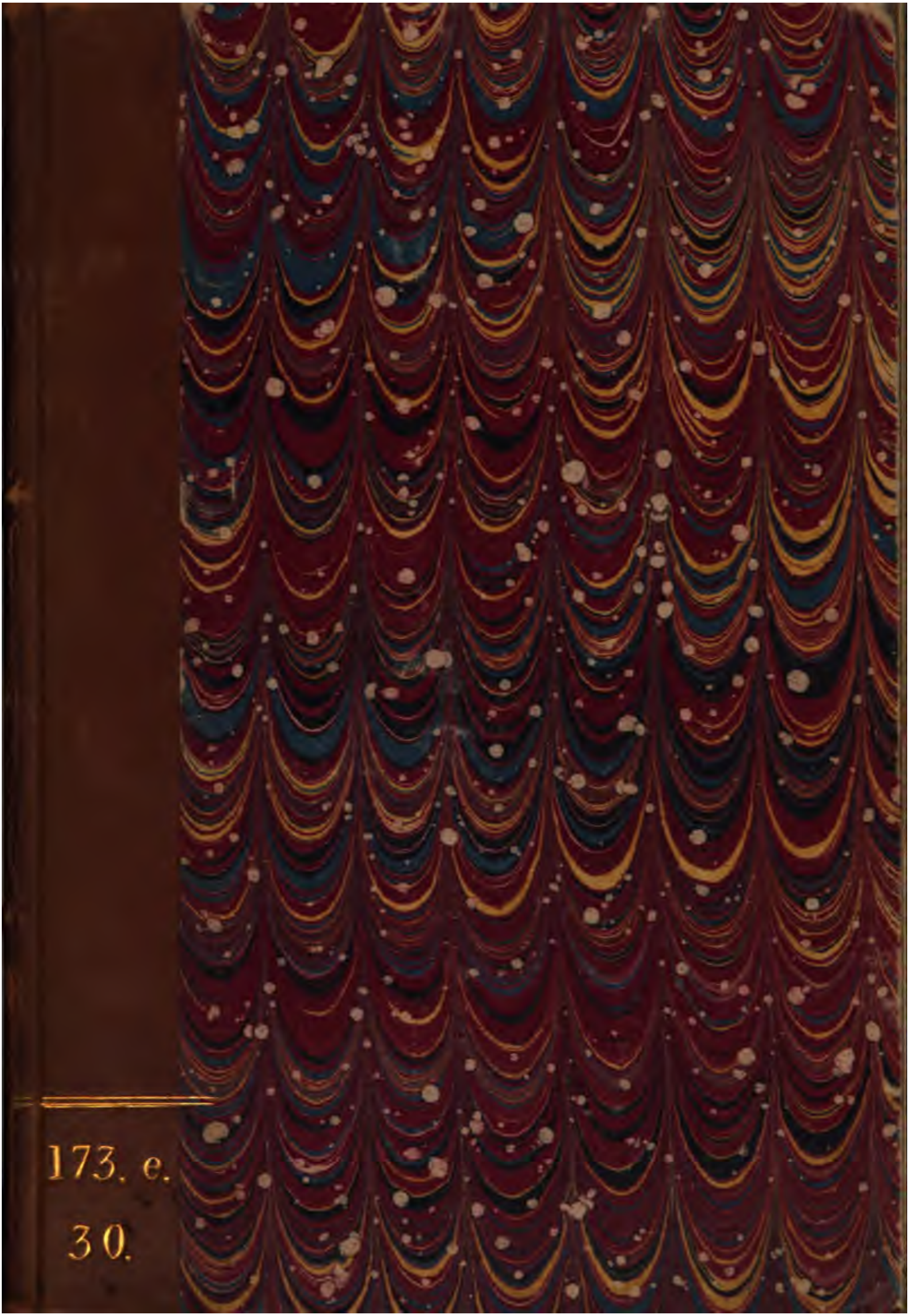

173. e.
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A KEY

TO

PROPORTIONS OF THE PARTHENON.

BY

JOSEPH JOPLING, ARCHITECT.

"I have found it! I have found it!"—*Archimedes.*

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A KEY
TO PROPORTIONS OF THE PARTHENON.

> "This perfect recovery of the light that guided the Athenian artists, can alone raise the arts connected with the geometry out of the errors that ages of darkness have cast around them; this alone can restore them to their true position among the exact sciences, and eventually place the arts of Europe on a level with the present advanced state of general science."—*John Pennethorne*, 1844.

It is left to others to determine the cause hitherto, of the general very great "*want of perception*" of the necessity for a public exhibition of diagrams, models of curved solids, numerous simple apparatus and their curved results, consecutively and permanently arranged in a Gallery for inspection and comparison—for "*experiment and observation*"—for a far more extended knowledge of practical geometry than an individual unaided can ever accomplish; to instruct the mind and the eye, in reference to proportion and form of definite curved lines and curved surfaces, and their intersections, and projections, especially applicable to architecture; for unless true principles are accurately known, they cannot justly be either appreciated, or with strict propriety be introduced in design.

It is however some encouragement to persevere single handed, to be enabled to submit such a number of facts in immediate connexion, and these proved by geometrical construction and by calculation, which place beyond a doubt that the ancient Greeks have recorded in the Parthenon, much knowledge which has been since long lost, that they had acquired of geometrical laws, and to which their unrivalled success in architecture and the arts must be attributed.

Mr. Penrose's Measurements of Upper Step, with their differences and averages.

No.		Feet.	Difference.
1.	East end at top	101·341	·006
	West end at top	101·347	
		2)202·688	
	Average	101·344	
2.	North side at top	228·141	·013
	South side at top	228·154	
		2)456·295	
	Average	228·147	
3.	Inclination of upper step	·023	
	Average of end on top	101·344	
	Average of end at bottom	101·367	

4. Inclination of upper step	·023
Average of sides on top	228·147
Average of sides at bottom	228·170

On Proportion, 4 : 9.

These averages for the length of the bottom of the upper step at the ends, and the sides, form a parallelogram of very nearly the proportion 4 : 9; which proportion it is considered from the general evidence the mason's lines by which the steps were set, in reality originally was. Therefore:

5. To the average of ends at bottom	= 101·367
Allow for space for mason's line to hang clear of work—for any minute error in original setting out and in workmanship—also for alterations by time during more than 2000 years—and for any inaccuracy in the measurements by Mr. Penrose.	= ·073 !!!!
The calculated full length of ends as originally set out	= 101·440

6. Then the average of sides of upper step at bottom	= 228·170 long
Allow for space for mason's line, &c., as before, for ends	= ·073 !!!!

The calculated full length of sides as set out .... } = $\overline{228{\cdot}243}$

7. The half of ·073 = ·036; or less than one half of an inch, being added all round bottom of upper step as measured by Mr. Penrose, gives a parallelogram for the mason's line of

101·44 feet by 228·24 feet
in the exact proportion of
4 : 9.

SETTING OFF A RIGHT ANGLE, &c.

There are various ways by which a right angle may be formed, amongst which a right angled triangle can be made and such a parallelogram may be set off by the proportions 3, 4, and 5, geometrically; or by figures thus:

1 produced 3 times = 3 = one leg.
3 + 1 . = 4 = {another leg and end of parallelogram.
4 + 1 . = 5 = hypothenuse.
4 + 5 . = 9 = side of parallelogram.

Or, further, calculated from the full length of upper step at one end of the Parthenon, thus:

Full length, equal one leg .... } = $\dfrac{101{\cdot}44}{2}$ = 50·72 one $\frac{1}{2}$

$\dfrac{50{\cdot}72}{2}$ = 25·36 one $\frac{1}{4}$

$$\left.\begin{matrix}25{\cdot}36 + 3{\cdot} \text{ or}\\ 50{\cdot}72 + 25{\cdot}36\end{matrix}\right\} = 76{\cdot}08\left\{\begin{matrix}\text{another}\\ \text{leg}\end{matrix}\right.$$

$$101{\cdot}44 + 25{\cdot}36 = 126{\cdot}80 =$$

Hypothenuse.

$$101{\cdot}44 + 126{\cdot}80 = 228{\cdot}24 =$$

length of parallelogram = upper step at side. Or, with one half, or one quarter, or any other definite proportion of the full length of the end upper step, between the mason's lines at the sides, the other measures can be calculated, a right angle formed, and the breadth and length of a parallelogram of the upper step set off in the proportion of 4 to 9.

On the Curvature of Upper Step, &c.

Having advanced thus far, and supposing that stakes or blocks of stone to be fixed outside at the four angles of the temple, and to and from these the mason's lines fixed and stretched, at ends and sides, by which to guide the workmen to set the blocks for the upper step:—the thought occurred to the author that, although on a horizontal plane, these mason's lines would appear as right lines; yet, as they would swag, on vertical planes they would be catenary curves; and that just as much as these may be below a horizontal line at every point, if set off as much above, might give the delicate curve of the top of the upper step, at any number of points.

This very simple method on trial has been found to be correct. Exactly coinciding with Mr. Penrose s points. Thus the ancient Greeks knew and applied in architecture, catenary curves ! !

The curve the full length at East end of the upper step the author set off; and also the curve of the Entasis the full length of a column, at the Architectural Museum, Canon Row, Parliament Street, Westminster, for a lecture on the 28th of May, 1855.

The model still remains there for the inspection, and it is to be hoped, for the conviction of some of those who have doubted the very existence and have ridiculed the idea of such delicately varying lines having ever been applied in architectural constructions.

Other delicate curves, as for the architrave above the columns, &c., may be set off in the same way, with facility and great accuracy.

Such curves, although perfectly distinct on the full sized scale, and even on a very minute scale, the eye may be instructed to observe very delicate variations in lines, they cannot well be represented on the paper of a book.

On the peculiar arrangement of the exterior Columns surrounding the Parthenon.

In order that the positions of the columns at the sides and the ends of the Parthenon should perfectly harmonize, it was seen to be necessary to make centres of fourth openings between columns at the sides, at the same distance from the angles, as from the angles to the centres of the ends; also in counting from sides the middles of fourth openings.

By setting off one half the length of the end of the parallelogram from each angle along the sides, the sides are thus divided into three spaces; viz., $50{\cdot}72 + 126{\cdot}8 + 50{\cdot}72 = 228{\cdot}24 =$ the full length of a side = the longest leg added to the hypothenuse The ends into two $50{\cdot}72 + 50{\cdot}72 = 101{\cdot}44$.

Then the $\frac{126{\cdot}8}{9} = 14{\cdot}08888 =$ the general distance from centre to centre of columns.

There are 14 of these equal divisions on each side; therefore $14{\cdot}08888 \times 14 = 197{\cdot}24444 =$ distance between the centres of second columns from the ends; and there are 5 of these equal divisions at each end, therefore $14{\cdot}08888 \times 5 = 70{\cdot}4444 =$ distance between second columns from each side.

Now, $228{\cdot}24 - 197{\cdot}24444 = 30{\cdot}99555$.

and, $101{\cdot}44 - 70{\cdot}4444 = 30{\cdot}99555$.

again $\frac{30{\cdot}99555}{2} = 15{\cdot}49777 =$ the distance from corner of the upper step (mason's line) to the centre of the second column, both at the sides and at the ends.

$$\left.\begin{array}{ll}\text{Next,} & 15{\cdot}49777 - 14{\cdot}08888 \\ \text{and} & \dfrac{14{\cdot}08888}{10}\end{array}\right\} = 1{\cdot}40888.$$

This, thus, twice derived number, is proposed to be called *the pivot.*

On the exact position and dimension of the surrounding Columns.

This number 1·40888, is the difference between the sides of an inscribed and a circumscribed square to a circle: and 1·40888 is also the side of a square; the diagonal of which is 1·9922; and 1·9922 + 1·40888 = 3·4011 = the distance from the mason's line to the line of centres of all the columns at the sides and the ends of temple; and also = to the side of the inscribed square; the diagonal of which is = 4·8099 = the side of circumscribed square, and = the top diameter of intermediate columns.

Again, 4·8099 + 1·40888 = 6·2188 = diameter *of* intermediate columns ***at bottom.***

Further, the sum of the sides of the inscribed square = 3·4011 × 4 = ... 13·6044;
and the sum of the sides of the circumscribed square = 4.8099 × 4 = ... 19·2399;

Sum of sides of both squares = ... 32·8444

Then 32·8444 — 1·40888 = 31·4355 = height of shaft of column, and 31·4355 + $\frac{3{\cdot}4011}{2}$ = 33·1360 = height to abacas; next 32·8444 + 1·40888 = 34·2533 = full height of column to top of abacas. Further, 3·4011 × 2 = 6·8022 = breadth, or side of square of abacas. And, 34·2533 — 31·4355 = 1·40888 × 2 = 2·8177 = height of curved portion of capital.

To conclude, $\frac{1{\cdot}40888}{2}$ = ·70444 = varsed-sine to the chord, the side of inscribed square; also it is the side of a square, formed by producing sides of inscribed square to sides of circumscribed square. The diagonal of this square = ·9961, and $\frac{6·2188}{2}$ = 3·1094 = radius at bottom; and last, $\frac{4·8099}{2}$ = 2·4049 = radius at top of column.

All this, when set out geometrically full size, becomes simple and quite obvious: or by diagrams may be illustrated.

By the process described every necessary dimension is obtained for more than *fifty thousand superficial feet of the surface of the Parthenon being executed accurately;* or if the whole of the parallelogram enclosed by the upper step be taken, *more than seventy thousand superficial feet!* and, all this in proportion for a building of any other size, may be obtained by the same process from any given length for end upper step: and doubtless all the process to execute every other proportion in the temple may now be rediscovered.

Very much of what is now given might be set out and exhibited full size temporarily, at the Architectural Museum; and permanently, as well as the curves of the upper step and the entasis of the columns, be placed in the British Museum, for which space can be pointed out, in connexion with the remains of the Parthenon there; for the inspection and instruction of the tens of thousands who visit that Temple of Knowledge.

The following comparison of Mr. Penrose's measurements with the author's calculations it is hoped will make this process distinct.

AN ARRANGEMENT OF THESE MEASUREMENTS OF THE PARTHENON, BY MR. PENROSE, AND THE RESULTS OF AUTHOR'S CALCULATIONS COMPARED.

No.	Averages from Mr. Penrose's Measurements	Author's Calculations from.	
1	101·367	101·44	The length of upper step at ends given, to find the following. This is equal one leg of a right angled triangle.
2	50·683	50·72	= one half of end = distance to centre of fourth opening at sides from ends.
3	25·341	25·36	= one quarter of end and one ninth of side.
4	76·024	76.08	= three quarters of end = another leg of a right angled triangle.
5	228·170	228·24	= the length of upper step at sides = 101·44 + 101·44 + 25·36.
6	126·803	126·80	= hypothenuse of right angled triangle = upper step at sides, less upper step at ends = $^5/_9$ of side.
7	14·083	14·08888	= one ninth of $^5/_9$ of sides = general distance from centre to centre of columns.
8	197·166	197·24444	= fourteen times $^1/_9$ of $^5/_9$ of side = the sum of the number of equal divisions from centres of second columns from ends.
9	………	70·4444	= five times $^1/_9$ of $^5/_9$ of side = the sum of the number of equal divisions at ends from centres of second columns from sides.
10	30·974	30·9555	= 228·24 — 197·24444. The half of 30·99555 =.
11	15·487	15·49777	= from mason's line to centre of second column, each way from all the corners, ends and sides.
12	………	1·40888	= *the pivot*, or 15·49777 — 14·08888: also the difference between the sides of an inscribed and circumscribed square to a circle, and $^1/_{10}$ of $^1/_9$ of $^5/_9$ of side.
13	………	1·9922	= the diagonal of a square whose side is 1·40888, also the difference of the distances from centres of columns = 14·0888 — 12·0966.

14	3 357	3·4011	= the sum of 1·9922 + 1·40888 = the distance from the mason's line to the line of centres of columns on each side and each end; also = side of inscribed square.
15	....	12·09666	= 15·49777 — 3.4011 = distance from centre of angle columns to centre of second columns each way from each angle.
16	....	1·7005	= half of side of inscribed square.
17	4·816	4·8099	= the diagonal of the inscribed square; also, the side of circumscribed square, and top diameter of column.
18	6·25	6·2188	= the sum of 4·8099 + 1·40888 = bottom diameter of column.
19	....	13·6044	= the sum of the sides of the inscribed square = 3·4011 × 4.
20	....	19·2399	= the sum of the sides of the circumscribed square = 4·8099 × 4.
21	....	32·8444	= the sum of the sides of both squares.
22	31·432	31·4355	= the sum of the sides of both squares, *less the pivot*, = 1·40888 = the height of the shaft of column.
23	....	33·1360	= the height of the shaft *added* to 1.7005 = half the side of inscribed square = height to abacas.
24	34·25	34·2533	= the sum of the sides of both squares *added to the pivot* = the full height of column, to top of abacas.
25	1·145 1·125	1·116	= depth of abacas.
26	6·858 6·757	6·8022	= twice side of inscribed square = breadth of abacas, or side of its square.
27	2·818	2·8177	= height of curved portion of capital = 1·40888 × 2.
28	....	·70444	= versed-sine to chord of side of inscribed square, also a side of a square.
29	....	·9961	= diagonal of this square.
30	3·125	3·1094	= radius at bottom of column.
31	2·408	2·4049	= radius at top of column + ·70444 = 3·1094.

N.B.—To some of Mr. Penrose's measures must be added the space, or twice the space, for the mason's line to hang clear, as well as the inclination of upper step; and to others a proportion of these quantities.

Capital of Columns.

I have not had the *opportunity* of sufficiently examining and studying Mr. Penrose's large book, to enable me to determine the probable character and source of the curved profile of the capital, or whether it is one line, or composed of two parts of different curves. In either case, I doubt not but that it will be found in the Septenary system, or connected therewith, and with *curved* and *plane* sections of curved solids.

Flutes of Columns.

From a first trial, the sections of the flutes appear to be elliptical. An arc of an ellipse whose diameters are in the proportion of 4 : 9, appears applicable at the bottom of the column. The depths of the flutes it is considered may be deduced from the calculations made. The sections of the flutes at the top of the column indicate an arc of an isometrical ellipse.

With a mould to the horizontal section at the bottom of the column, the whole length of each flute may be adjusted, or any number of elliptical arcs for horizontal sections at every point required in the height, may be easily practically determined.

The flutes of columns may have been introduced to mark more distinctly their profile, as well as to multiply variety between the delicate curve of the entasis and a pefect right line; similar to what must take place in the vibrations of a harp string.*

---

* The irregular lines of reflection of the entasis of the granite columns in Pall Mall, from the polished surface, does not add to their beauty.

Modifications, &c.

The delicate curves, the flutes, the inclination and the increase in the size of the angle columns, may have been introduced to hide as well as give variety to, and to clothe the more simple and strictly geometrical laws. For the same reason the quickest point in the curve, of which a portion is the entasis, is hidden in the ground; and the points from which the mason's lines were stretched are obliterated.

During the erection of such a work as the Parthenon—wet and dry weather—heat and cold—storm and calm—not to say wear and tare of moulds, of whatever material they were made, may have produced some variation from the strict laws followed, with such care by all the workmen employed, that it is scarcely perceptible.

Remarks.

Before so many results as have been obtained from the length of the end upper step of the Parthenon by the train followed, it will be manifest that

First—Such must have been the laws of the original design.

Second—The work must have been accurately executed.

Third—That sufficient of the Temple must have endured for twenty-three centuries.

Fourth—And that the measurements by Mr. Penrose must clearly have been as carefully made as the original work was executed.

This may be considered one of the wonders of the world. What other building will admit of such close investigation?

If I had no other means to judge from than the excellent speech of His Royal Highness Prince Albert, so recently at Birmingham, the eternal laws of proportion and form to which I have so long invited attention, would be of the greatest value there, if adequately represented.

Will any one after knowing what His Royal Highness has just said, venture to make the War an excuse for delaying the commencement of an extensive survey and exhibition of the results of the laws of truth and distinctiveness of character, for improving and varying by just principles every object of art?

The minute and delicate and other exact curves and proportions in the Parthenon, doubtless tended greatly to inspire the sculptor's mind, and to instruct the eye *truly to observe.* But, from the finest specimens of sculpture, the eternal, natural, and geometrical laws for the forms and the proportions of the frame work (strictly the architecture,) of the Parthenon, could never have been deduced.

To record all that is desirable on the parts referred to on this interesting subject, would require a much larger work with several diagrams; but it is hoped that sufficient has been given to justify the title—A Key to Proportions of the Parthenon—even if the following test be applied:

> "If the results obtained by calculations made according to the theory, do not in every instance, mathematically agree with those derived from measurements of the buildings, then the theory may be laid aside as a mere speculative fancy unsupported by evidence."—*Pennethorne.*

THE END.

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A KEY

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PROPORTIONS OF THE PARTHENON.

BY

JOSEPH JOPLING, ARCHITECT.

> "I have found it! I have found it."—*Archimedes.*

No. II.

WITH SEVENTEEN DIAGRAMS.

BODLEIANA · BIBLIOTHECA

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1856.

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BIBLIOTHECA·BODLEIANA

A KEY

TO PROPORTIONS OF THE PARTHENON.

No. II.

At the conclusion of the First Part of this Work it was intimated "To record all that is desirable, would require a much larger work with several diagrams."

Further progress having been made, a few wood cuts being considered essential for easy comprehension, with an effort these and some additional facts had been arranged;

When on the 18th of January, 1856, I received, to take home, Mr. Penrose's Work on "Principles of Athenian Architecture," from the "Architectural Museum," for a short time to examine and study.

This has added something more, which will appear in the progress.

The Pivot.

It has been shewn that the distance from the *mason's line* to the centre of second columns each way from all the angles is .... = 15·4977

And that the average distance from

centre to centre of all other columns
surrounding the Parthenon is .... = 14·0888

The difference—*the Pivot* .... = 1·4088

This being exactly equal $\frac{1}{10}$ of .... 14·0888

and consequently is $\frac{1}{11}$ of .... 15·4977

It was soon discovered that *the Pivot* would divide the upper step at both the ends and the sides into equal parts, thus:

$$\left.\begin{array}{ll}\text{Ends}\ldots\ldots\ldots\ldots & \dfrac{101{\cdot}44}{72}\\[2ex] \text{Sides}\ldots\ldots\ldots\ldots & \dfrac{228{\cdot}24}{162}\end{array}\right\} = 1{\cdot}40888 \text{ the Pivot.}$$

and also

$$\left.\begin{array}{ll}\frac{3}{4}\text{ of end }\ldots\ldots & \dfrac{76{\cdot}08}{54}\\[2ex] \left.\begin{array}{l}\frac{5}{4}\text{ of end}\ldots\\ \quad\text{or}\\ \frac{5}{9}\text{ of side}\ldots\end{array}\right\} & \dfrac{126{\cdot}80}{90}\end{array}\right\} = 1{\cdot}40888 \quad \text{ditto.}$$

It was therefore thought possible that this being thus so evidently *a unit*, may have been some standard measure of the ancient Greeks.

The diagonal of a square whose side
is 1· is .... = 1·41421
the Pivot being .... = 1·40888
and if it be taken as a diagonal, it indicates the side of a square approximating very closely to 1· or .... = ·9961
also if *the Pivot* .... = 1·40888
be the side of a square, the diagonal of
that square will be .... = 1·9922.

This is a very near approximation to the two-feet English rule, standard measure.

This process of alternately making a measure either the side or diagonal of a square, may be continued either way, to increase or diminish measures in proportion.

These were then compared with the following, selected from recorded measures.

Table I.

English one foot	= 1·000	
Nuremburg town foot	= ·997	Vega.
Derived from *the Pivot*	= ·9961	
Nuremburg town foot	= ·996	Hutton.
Florence foot	= ·995	ditto.

Table II.

Bargamo foot	= 1·431	ditto.
Milan aliprand foot	= 1·426	ditto.
Diagonal of a square whose side is 1· foot	= 1·41421	
The Pivot (Parthenon)	= 1·4088	
Padua foot	= 1·406	ditto.

Table III.

English two feet rule	= 2·000	
Diagonal of square whose side is the Pivot 1·40888	= 1·9922	
Lucca Braccio	= 1·958	Cavallo.
Prague ell	= 1·948	Vega.
Geneva foot	= 1·919	Hutton.

The previous were arranged before seeing that Mr. Penrose gives:

Roman foot .... $\left\{\begin{array}{l} = \cdot968 \\ = \cdot972 \\ = \cdot973 \end{array}\right.$

Greek foot .... $\left\{\begin{array}{l} = 1\cdot008 \\ = 1\cdot014 \\ = 1\cdot0125 \end{array}\right.$

= 1·014 *

= 1·0125; this he adopts to measure upper step, but any reference to a Greek foot less than the English foot has not been observed in his Work.

The application of the Pivot as the side of a square and its diagonal to give the distance from the mason's line to the centres of all the columns has been explained, but will be much better understood by the diagram, figure 4, when that comes to be described, at page 27.

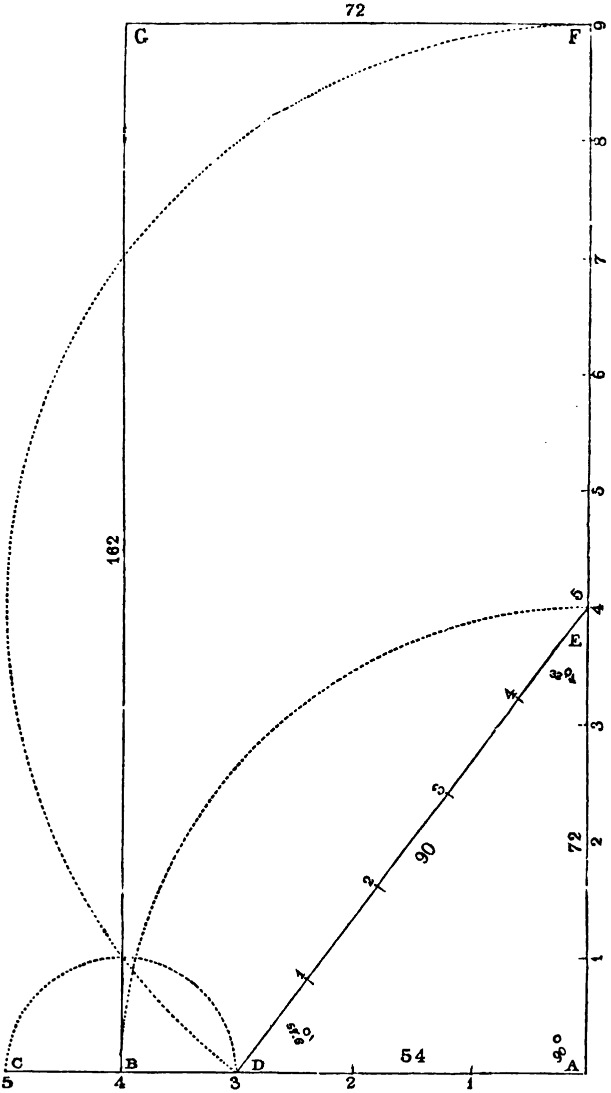
Plan of Outline Upper Step.

Fig. 1 is the plan of the outline of the upper step (mason's line), shewing how, from a given length, for the end to obtain *five* equal divisions geometrically, and then to set off a right angle by the proportions 3, 4, and 5; and next, producing the longer leg for the side of the parallelogram until it

---

* The measure I have taken for the breadth (mason's lines) upper step = 101·44; and this $\frac{101\cdot44}{100}$ = 1·0144; is a close approximation to this Greek foot given by Mr. Penrose as the largest limit.

Fig. 1.



is in the proportion of 9 : 4. See page 6, first part of Key.

In addition to shewing the end, by bisection, divided into four equal parts, and AB being produced to C to obtain *five* equal parts, which are applied in forming the right angled triangle ADE, producing AE to F, and then setting off nine divisions, and completing the parallelogram—the relative proportions of the sides of the right angled triangle, viz., 54, 72, and 90, and of the parallelogram, viz., 162 and 72, by the same unit of measure the Pivot are given upon this plan, (these will be referred to hereafter,) and also the angles of a triangle whose sides are 3, 4, and 5, viz., 32°·4, 57°·6, and 90° are added.

The Plan of Upper Step with the Arrangement of the Centres of Columns.

Fig. 2. The outline of this figure is the same as the parallelogram in figure 1.

The peculiar arrangement of the centres of exterior columns, explained from pages 8 to 11 inclusive, is given in this plan, with the dimensions, except the general distance between centres and centres of columns 14·0888.

This division $\frac{1}{9}$ of $\frac{5}{9}$ of sides, and $\frac{1}{9}$ of $\frac{5}{4}$ of ends (explained in the next figure) is subsequently divided by 10, for the Pivot.

Outline plans of figs. 1 and 2 were sent to the *Builder*, with explanations, in February, 1854, but returned on the 2nd of June in that year, before the Crystal Palace at Sydenham was opened. Communications had been previously made to Mr.

Penrose in November and December, 1853, in reference to this and the application of the Catenary curve to upper step of Parthenon.

Fig. 2.

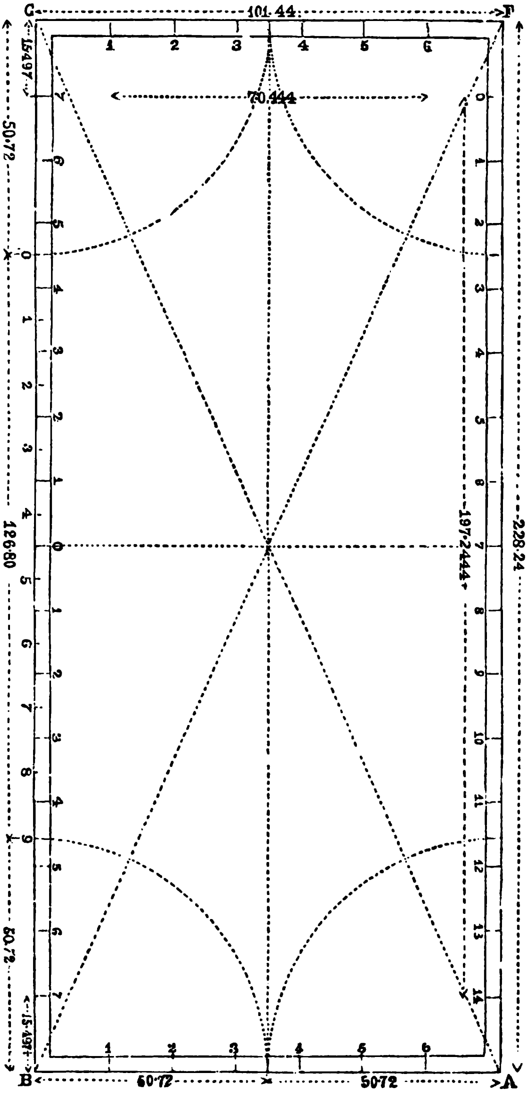


Fig. 3.

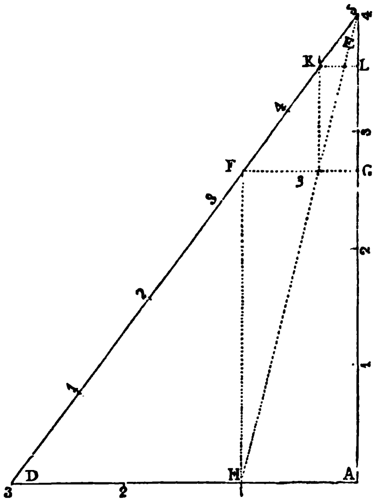


Fig. 3 shews the geometrical process of obtaining $\frac{1}{9}$ of $\frac{5}{9}$, as set out on fig. 2. The sides of the right angled triangle being in the proportions of 3, 4, and 5, and are on fig. 3 thus divided:

A perpendicular erected from $\frac{1}{3}$ of the shorter leg, cuts off $\frac{1}{3}$ of the hypothenuse: and a perpendicular let fall from that point of the hypothenuse on to the longer leg, cuts off $\frac{1}{3}$ of that.

Then from $\frac{1}{3}$ on the shorter leg draw the line H E, and then $\frac{1}{3}$ of the perpendicular F C is cut off. Next erect a perpendicular from the $\frac{1}{3}$ of FG to cross the hypothenuse at K, and $\frac{1}{3}$ of $\frac{1}{3}$ is cut off, being $\frac{1}{9}$ of $\frac{5}{9}$ (the hypothenuse) of 228·24 = 14·0888. This is applied in the divisions on fig. 2; the general distance from centre to centre of columns;

and of centre to centre of openings between columns.

On the Division of a Circle into 360°.

Before the appropriateness and harmony of the divisions just explained and used in the Parthenon, and others which are to follow, can be fully comprehended, it appears desirable to describe a process for the division of a circle into 360°; which peculiar division, from facts found recorded in the Parthenon, prove it to have been known and practised before that structure was designed, if there is no other evidence when such a division was first made.

Various other divisions of a circle are of great importance in giving harmonious variety and distinctiveness of character to forms and designs, on which much might be written.

But to return to the peculiar division of 360°. This number may be divided by all the digits except 7, without a remainder.

The *first* step in such a division of a circle is to draw a diameter across it; the *second*, another diameter at right angles to the first; thus bisecting the whole circle, and then each half, by which the circular line is divided into four equal parts or quarters.

The division of the end upper step, fig. 1, into four equal parts, may be considered analogous to this.

Each of the quarters of the circle is then divided by the radius into three equal parts.

In the division of a right line into four, three parts are also obtained, which are required, as well as the four, by the process used in setting off a right angle.

The next division of the circle required is the trisection of $\frac{1}{3}$ of $\frac{1}{4}$ to obtain $\frac{1}{9}$ of the quadrant.

This possibly may have first suggested the *trisection of an angle;* which practically, can be accomplished, as accurately, with proportionate facility, and by as direct means, as simple bisection.

Or any angle, with proportionate facility, and equal accuracy, can be divided practically into any number of equal parts.

The process of dividing a right line into *three*, and its *third* into *three*, is shewn in the diagram fig. 3.

The last division of the circle to obtain one degree of 360°, is to divide $\frac{1}{9}$ of $\frac{1}{4}$ into ten equal parts. The first step in this last stage is by bisection, which gives a division equal to five degrees.

Here the same geometrical difficulty would arise as in the trisection; but this, as has been stated, can practically be as accurately made as bisection.

And the division of a given right line into *five* equal parts can be accomplished geometrically in the same way as the divisions into three and nine, which have been explained.

Thus we have a division by *five*, analogous to the five divisions used with the *three* and the *four* in setting off a right angle, and which assists in the peculiar arrangements of the columns surrounding the Parthenon.

Each $\frac{1}{9}$ of $\frac{5}{9}$ is thus divided:

$$\frac{14\cdot0888}{10} = 1\cdot40888 = \text{Pivot.}$$

So the Pivot may be considered to be obtained by a division analogous to that by which one degree of a circle is determined.

Fig. 4—(page 28).

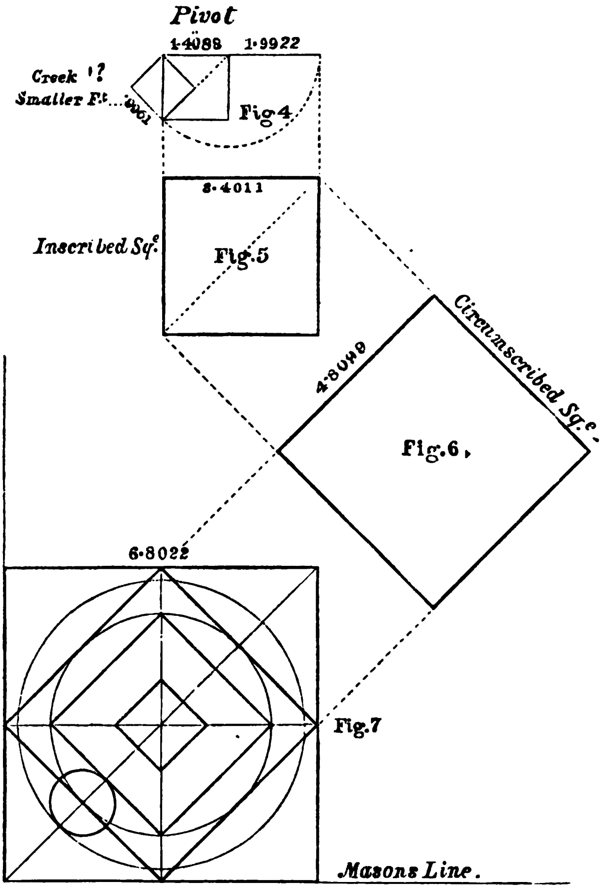
Here a square is represented, whose side = 1·40888 (the Pivot); on one side of which is shewn the diagonal = 1·9922 produced; and on the other side the Pivot is the diagonal of a square, whose side = ·9961; perhaps equal to a smaller Greek foot?

Fig. 5—(page 28).

A square, the side of which is derived from the side and the diagonal of Pivot square fig. 4, is the *inscribed square* to the circle at the top of the shaft of the column, the side of which is = 3·4011.

Fig. 6—(page 28).

Is the *circumscribed square* to the same circle. The side of this square = 4·8099, being equal to the diagonal of square fig. 5.



Plan of intermediate columns.

Fig. 7.

In this the figures 4, 5, and 6 are combined, with the circles at top and bottom of the intermediate columns. The outer circle being in diameter greater than the inner by 1·40888, the Pivot; or in radius by ·70444 = versed sine to side of inscribed square, shewn by small circle.

The square circumscribing diagonally, the square circumscribing the circle at the top of the shaft, gives the plan of the abacas, and the position of the mason's line from centres of all the columns at bottom on upper step.

Fig. 8.

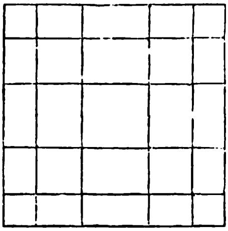
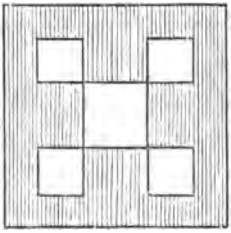


Fig. 8 is formed from fig. 7, and something like it is represented on a small scale on a fillet in Mr. Penrose's Work (*plate* 22).

Fig. 9.

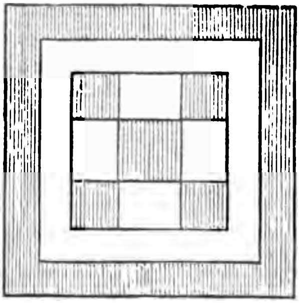


Is formed from the square of the Pivot, and the inscribed and circumscribed square to the circle at the top of the shaft of the column.

The law by which so much of the columns were proportioned, may be indicated by a figure in the fret on the architrave band, resembling this. The other lines of the fret may also have a reference to the same.

What is there in this fret, except that it may contain evidence of some knowledge that would entitle it to so important a position as it occupies? (See plate 22, Mr. P.'s Work.)

Fig. 10.



This is formed from the square of the Pivot, the inscribed and circumscribed square to circle at top of shaft, and also circumscribed square to circle at bottom of columns.

In another fret, something like this may have indicated so much more of the law by which the columns were proportioned. (See plate 22, Mr. P.'s book.)

Figs. 8, 9, and 10 have been introduced since having had Mr. P's. book to study.

To enter into the evidences in Mr. Penrose's Work "on the Principles of Athenian Architecture," (which he has not touched) of a knowledge by the Greeks not only of the plane conic sections, but also of curved sections of cones and other curved solids, geometrically, and of apparatus for describing curves, &c., opens out far too large a work to be attempted unaided.

For the increase of the Diameter or Radius of Angle Columns.

It has been seen that the distance
from the centre of the second columns
each way from the angles.................... = 15·4977
One tenth of which is .... = 1·54977
And one tenth of latter.................... = ·15497
for increase in diameter.

Then $\frac{\cdot 15497}{2} = \cdot 077488$, a very appropriate increase in radius to the circles of intermediate columns, both at top and bottom, for angle columns.

The increase to the angle columns should be a parallel addition, as it would, if less at top, appear more tapering than the intermediate columns.

On the Circumscribed Circle for Base of intermediate Columns, and the increase for Angle Columns.

The diameter of intermediate columns at bottom as given by the diagram and calculations is 6·2188.

But as the circle would be reduced in profile by the parts cut off by the chords of the arcs of two flutes, let the diameter be increased by the versed sine to the chord of the flute, and the full diameter of the intermediate columns at bottom will then be 6·2188 + ·031 = 6·25; the exact measure given by Mr. Penrose.

The longest chord from cusp to cusp of flutes, (parallel to diameter of intermediate columns) = 6·2188
+ ·1549 .... = 6·3738
Additional increase for clothing
with entasis .... = ·0042

6.3780 =

Mr. Penrose's measure for diameter of circle of angle column at bottom.

On the Heights of different parts of the Columns.

From the diagrams now introduced and the explanations and dimensions given at page 10, the different heights, and how practically ascertained full size, will, it is hoped, be manifest.

Here it may be added, that the *point of contrary flexure* in the profile of the capital is = ·70444 (half the pivot) above the top of the shaft of the column. See fig. 12.

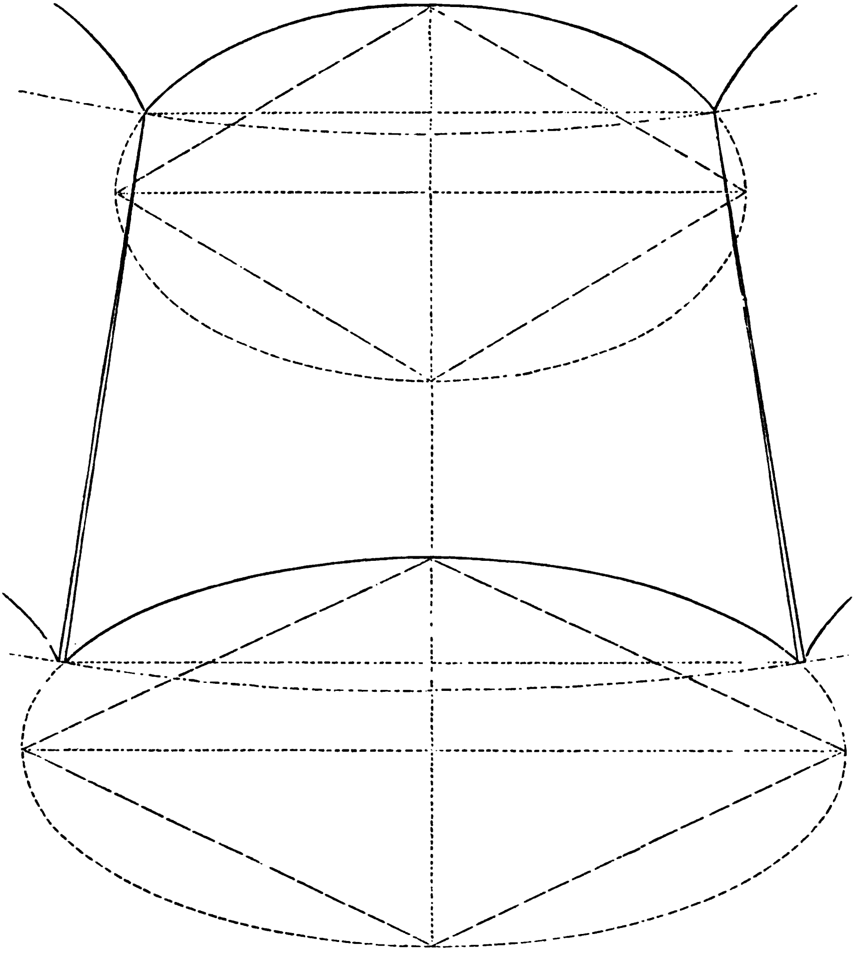
Fig. 11.

Flutes of Columns, second notice.

The number of flutes in the columns is 20,[*] and the number of degrees in each flute is 18°.

[*] See fig. 16.

Fig. 11.



These numbers are obtained by dividing

$$\frac{162}{9}\ \frac{90}{5}\ \frac{72}{4}\ \text{and}\ \frac{54}{3} = 18.$$

Also thus, 162 — 90 = 72 — 54 = 18, the number of degrees.

And $\frac{360^\circ}{18^\circ} = 20$ the number of flutes.

The depth of flutes for intermediate columns may be determined thus — The Pivot $= \frac{14{\cdot}0888}{100} =$ ·140888 the depth of flutes.

For angle columns — $\frac{15{\cdot}4977}{100} = {\cdot}15497 =$ depth of flutes.

This, the plan of a flute, $\frac{1}{3}$ full size, shewing elliptical arcs as sections, at top and bottom as intimated at page 14, will make evident this method of determining and adjusting the flutes at every part of their height with the greatest ease and accuracy by one mould.

The mould will be horizontal at the bottom, and be gradually inclined as the flute narrows, until the angle is about 40°. No other curve is so applicable for this as the ellipse.

Second Notice on Modifications.

Doubtless every modification was made by a law derived from something ascertained before, and to answer some object. With respect to the columns, the principal modifications are the following:

1st. The clothing of the shaft with an Entasis, not only to increase the thickness by its deviation from a chord, but also to give designed variety and increased beauty in appearance by the varying deviation of the edge of each flute from a right line on the elevation; and a trifle, as explained, may have been added to the dimensions determined, both at top and bottom by the process I have followed.

2nd. The inclination of the axis of the columns. This will have to be considered in reference to the point of contrary flexure in the profile of the Capital, and the full breadth of the temple at that height.

3rd. The abacas, as given by figure 7, is something *less* than that on the angle columns, and about as much *larger* than those on the intermediate columns. But doubtless that on figure 7 was the leading law.

The modifications from right lines in the longer curves for the steps and architraves may have been determined by a convenient force, by which "*the stretched line*" could be pulled.

Entasis, *&c.*

Mr. Penrose gives the definition of "*Entasis*" to be "*the stretched line, or bended bow*" *!*

Yet it does not appear that it ever occurred to him to try the catenary curve to any of "The minute and beautiful curves which the refined minds of the Greek artists led them to substitute for the straight lines and circular forms," "with which the Egyptians,"—"the Romans and their followers" (to the present time) "have been contented."

The greatest deviation of the Entasis from a right line may with great propriety be ·14088 = $\frac{1}{10}$ of Pivot.

The word "Catenary," is not to be found either in Mr. Penrose's "Glossary" or "Index."

The Architrave, &c.

Mr. Penrose gives the following measures with great accuracy for the Architrave, viz.,

15·227 feet.
13·966 —
13·889 —
14·210 —
14·128 —
13·617 —
15·263 —

100·300 = Total length in front.

He also gives for projection of abacus "·447" × 2 = ·894

101·194 = Total breadth of front at this part.

The point of contrary flexure in the Capital falls back from this ·79 × 2 .... = 1·580 = obtained from full sized drawing of Capital.

99·614 = 100 times ·9961, the

side of a square, to which the Pivot 1·4088 is the diagonal!!!! 99·61 = 100 times ·9961!! What extraordinary accuracy in the work of the old Greeks, and in the measurements of Mr. Penrose.

This breadth at the points of contrary flexure in the profiles of the Capitals of the angle columns is shewn in the next fig.

Fig. 12.

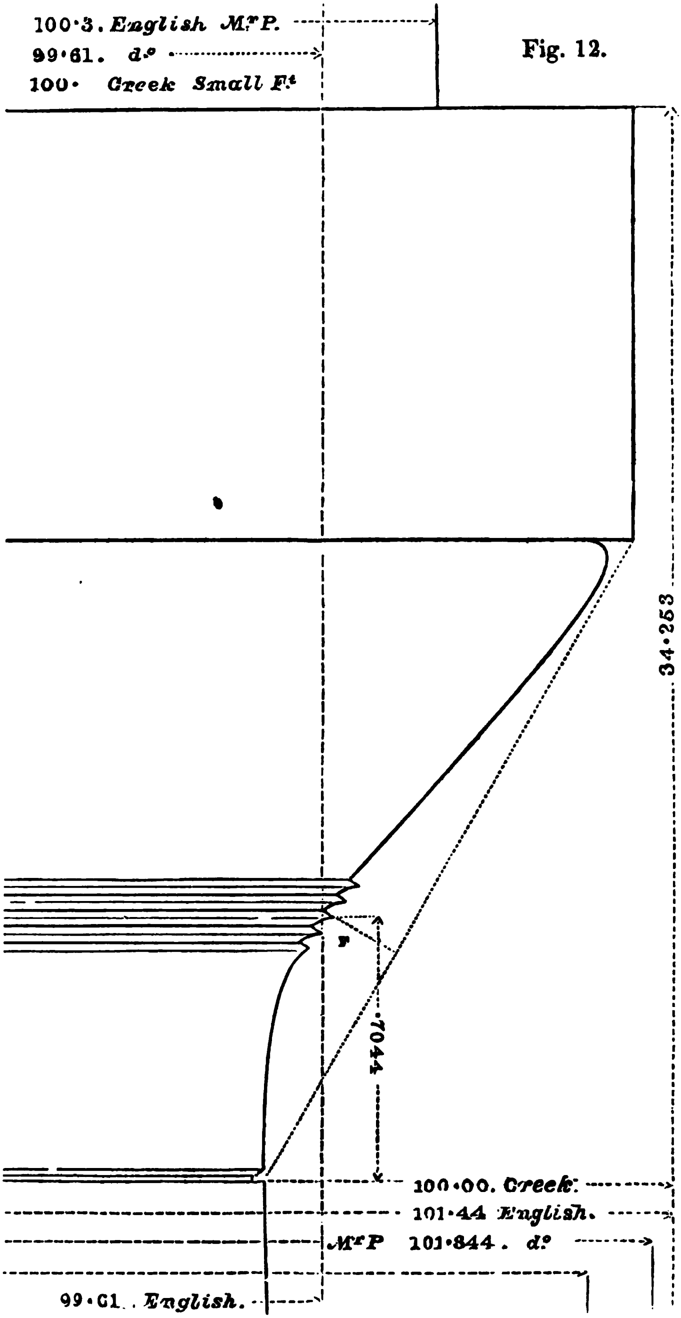
Second Notice on Capitals of Columns.

Having made from the dimensions given by Mr. Penrose, a profile of the Capital, full size, I have no hesitation in saying that portions of two catenary curves will give the line as accurately as any hyperbolas, or other curves. This can practically be made manifest.

It is right that it should be stated here that after I had shewn the application of the two catenary curves, full length, of the end upper step and the entasis of a column, at the Architectural Museum, Mr. Bruce Allen first thought of trying the catenary curves to the Capital.

On this figure is given one end of the Architrave as measured so accurately by Mr. Penrose, = 100·3 feet; and also a vertical dotted line through the point of contrary flexure between the two curves of the Capital, shewing how much that point is before the profile at the top of the shaft of the column: which, in fact, is the same as the inclination of the columns.

Fig. 12.


100·3. English Mr P.
99·61. do
100· Greek Small Ft
34·253
F
·7044
100·00. Greek.
101·44 English.
Mr P 101·844. do
99·61. English.

The breadth of the building at this height, between those points of contrary flexure in the profiles of the angle columns being = 99·61 = 100 × ·9961, given in fig. 4; and particularly explained under the head " Architrave, &c."

Points of Contrary Flexure.

Mr. Penrose gives in connexion with the profile of the Capital two points, one at the top of the shaft, and another in the midst of the fillets, already particularly noticed, which he calls points of contrary flexure.

In reality, however, they are not points of contrary flexure.

Of this, and that the line was not truly continuous, the ancient artists appear to have been aware; for, the one point at the top of the shaft is cut off from the curve of the Capital by the sinking, &c., in the neck, and the other point is covered, and the connexion of the two parts of the curved profile of Capital broken by the five fillets.

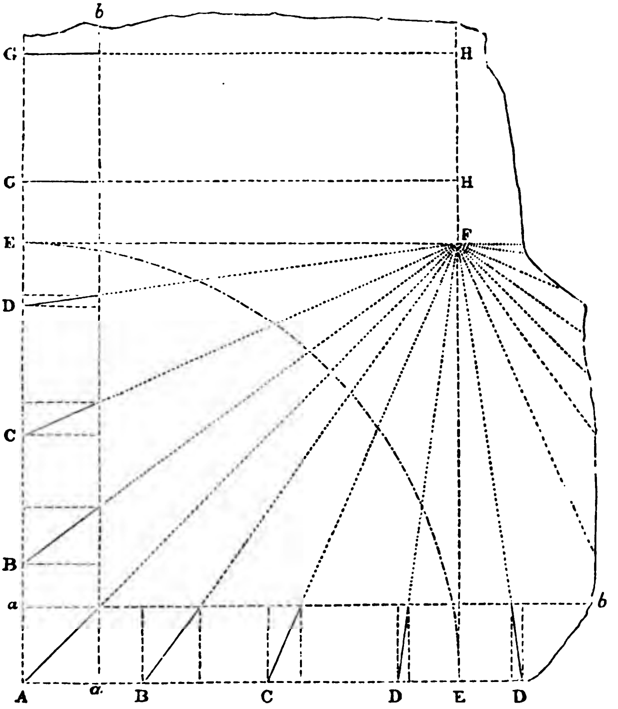
Fig. 13.

The Law of the Inclination of the Columns.

In fig. 13 the line AD passes through all the centres of the columns on the upper step at ends; and the line *a b* parallel to it, through all the centres of the columns at the top of the shafts.

The lines A G and *a b* parallel to it pass through

Fig. 13.



all the centres of columns at bottom and top of shafts at sides.

The radiating lines to F, shew by the dark parts, the axis of each column with the direction of its inclination projected upon the plan.

The quadrant of circle shews that E at the end and E at the side are at an equal distance from the angle A, as explained in fig. 2.

The lines of inclination of the axis of *nine* columns at each side are parallel to each other, as those marked G H.

As this agrees with what Mr. Penrose says, it confirms this to be the law by which the peculiar arrangement of the centres of the columns was determined, and which gives a less distance between the centres of the angle and second columns from each corner, than the general distance, for which Mr. Penrose says he was not able to account.

Mr. Penrose ascends by calculation "5856 feet" to give an idea of these several inclinations, which can in this way, practically and simply be set out full size, from a general inclination, to determine the diagonal inclination of the axis of each column.

Mr. Penrose, in his Letters from Athens, gives the inclination, ·229. In his large Work, ·135 and ·134.

I obtain from the length of the Architrave and the full sized profile of the Capital, ·160 for the inclination of the axis to the top of the shaft. Perhaps ·15497 may have been intended.

Second Notice on Proportion,

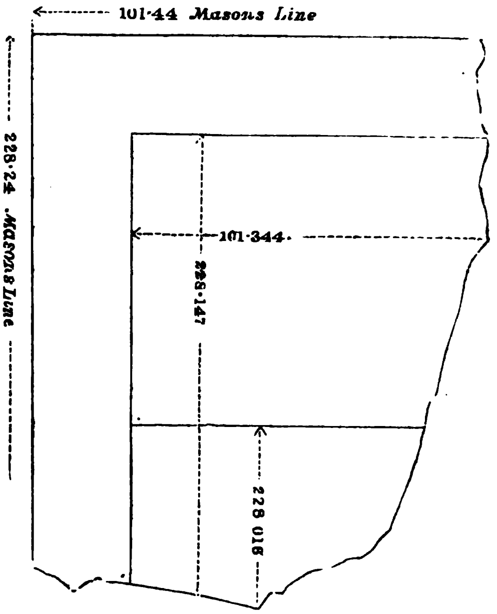
9 : 4.

Until examining Mr. Penrose's large Work recently, I did not know that he had said anything on this subject.

His measurements of the upper step not giving this proportion exactly, he has suggested that the difference may have been occasioned by the length of the Temple having been increased for some reason beyond what it was at first designed.

He therefore reduces the length from 228·144 to 228·016: these are shewn and the part cut off the length, full breadth, on fig. 14.

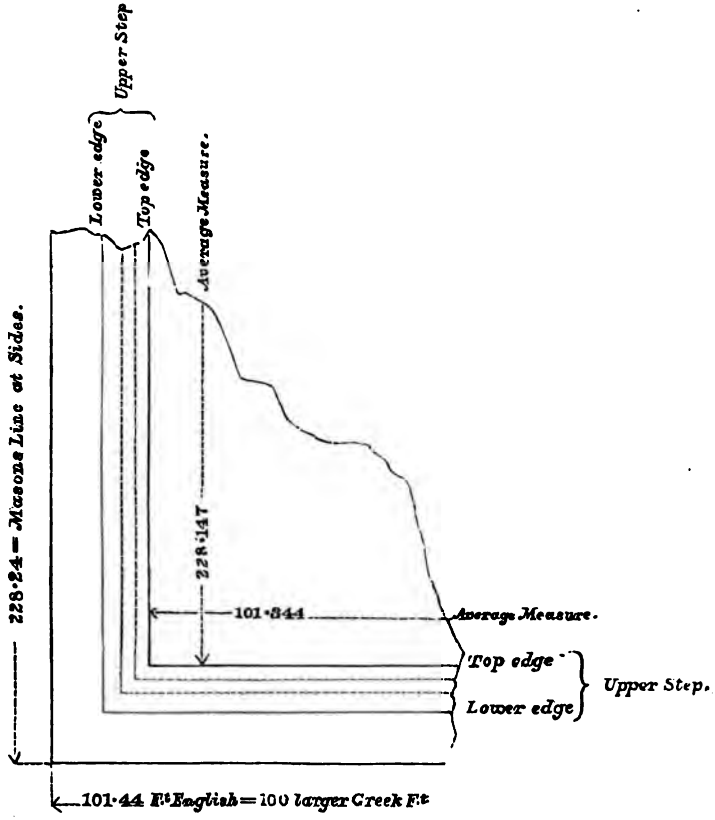
Fig. 14.



Without knowing what Mr. Penrose had done, I sought for a parallelogram in the proportion 9 : 4, equally distant outside, the measures given by him, and by which I obtained the positions of the mason's lines; which distance is shewn full size above here, and also on fig. 15.

From the measure of the breadth thus obtained, between the mason's lines, all the results have been deduced.

Fig. 15.



On the Inclination of Upper Step and the Position of Mason's Line.

Mr. Penrose, in his Letters from Athens, gives:

" West front: bottom of upper step.... = 101·370

Since the face of the step shares the inclination of the axis of the columns to the extent of ·023 "

He gives:

" West front: top of upper step .... = 101·347 "

·023

Thus making the inclination $\frac{\cdot023}{2} = \cdot0115$.

But in his larger work, plate 10, he gives:

" Bottom of upper step........................ = 101·356
At top... = 101·341 "

·015

Thus making the inclination $\frac{\cdot015}{2} = \cdot0075$.

On plate 8 he gives:

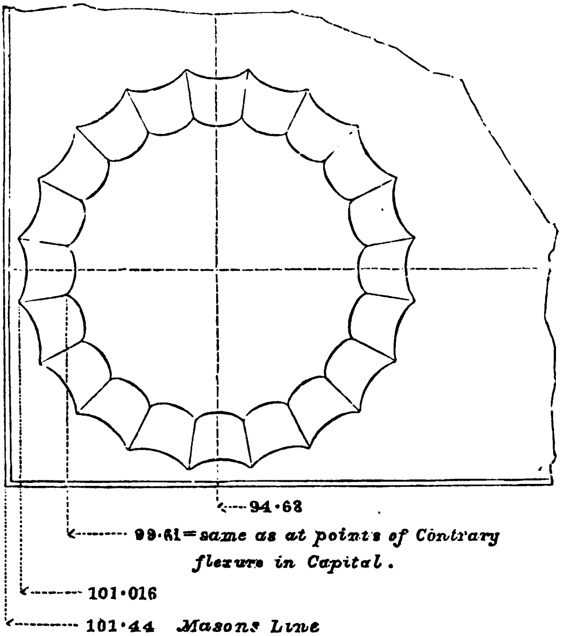
" Average inclination = ·007."

These are represented by the dotted lines on fig. 15, which also shews plan of angle on top edge of upper step, and position of mason's line full distance.

However, it is thought that the proper inclination for the upper step would be a line parallel to the tangent of the curve of the entasis at the bottom of the column. This is shewn by the line marked " lower edge " on fig. 15.

From this the mason's line would not be more than sufficient to keep clear of the work when stretched.

Fig. 16.



Plan of Angle Columns.

This, fig. 16, shews the plan of the angle columns at top of shaft and at bottom concentric with each other on top of upper step, with the mason's line.

The breadths of the Temple at the ends, between corresponding parts, are as follows:

1. From centre to centre of angle columns .... = 94·6377
2. Outside of profiles of top of shafts, shewn concentrical with plan at bottom .... = 99·61

(This is the same as between points of contrary flexure in Capitals = ·9961 × 100, which see in fig. 12.)

3. Outside of profiles of plan of columns at bottom .... = 101·016
4. Top of upper step........................ ...... = 101·344
5. Mason's line .... = 101·44

$\frac{101\cdot44}{100} = 1\cdot0144$; possibly it is thought the true larger Greek foot.

Hecatompedon.

This term having "suggested the idea that the ancient measure of Greece is to be found in some of its leading dimensions":

It appears desirable that particular attention should be directed to the fact that 1·0144, which is so nearly equal 1·014, a limit of the measure of a Greek foot given (but not adopted) by Mr. Penrose, and which is exactly the 100th part of 101·44 feet, which I have taken for the length of the upper step, and from which I have derived so many dimensions, and amongst the rest ·9961, which being multiplied by 100, gives another length in so peculiar a position, as to render it also, it is submitted, probable, 100 times another Greek foot.

These measures are given at No. 2 and 5 in the last article. From the smaller foot the larger may be obtained, thus. This ·9961, the supposed smaller Greek foot. Then $\sqrt{\cdot9961^2 \times}\ 2 = 1.4088$ the Pivot. Next $1\cdot4088 \times 72 = 101\cdot44$ the length of the end upper step.

And $\frac{101\cdot44}{100} = 1\cdot0144$ the larger Greek foot.

Averages.

The averaging principle, it is submitted, is liable to increase errors, if either the largest or smallest measure is in any case nearest the right one.

Although I have averaged Mr. Penrose's largest measures, the measure fixed upon as the true parallelogram of 9 : 4, is outside of the greatest measures given by him, and therefore not likely to be too small.

The accuracy with which, from the breadth thus taken, so many facts are obtained—particularly for the *pivot*, and the full height of the column = 34·253
Mr. Penrose's measurement being... .... = 34·25

and,

Especially the exact measure of 100 times ·9961, being found in so peculiar a position as the breadth of the Temple at the points of contrary flexure in the Capital.

If, in reality, there is any variation from the exact proportions of figs. 8, 9, and 10, has the averaging principle had anything to do with it?

Units of Measure.

1. In whatever way the length of the upper step was first determined to be = 101·44, its unit of measure is $\frac{101{\cdot}44}{100}$ .... = 1·0144
2. $\frac{101{\cdot}44}{4}$ gives a unit of measure .... = 25·36 which divides the side into 9.

3. $25{\cdot}36 \times 5 = \frac{126{\cdot}80}{9}$ gives.................. = 14·088
This is applied 38 *times* in the division of the distances between centres of columns.

4. $\frac{14{\cdot}088}{10}$ = the Pivot .... = 1·4088

$$\left.\begin{array}{lr}\text{This divides the ends into ....} & 72\\ \text{The sides into ....} & 162\end{array}\right\}\times 2$$

= the circuit of upper step into 468 times.

Shorter leg of triangle into.... 54
Larger ditto ditto into 72
Hypothenuse ditto ditto........ 90
The circuit of this triangle.... 216 times.

5. And 1·4088 is the side of a square, which being added to its diagonal 1·9922, gives the side of the inscribed square .... = 3·4011

6. From 3·4011 + 1·4088 is obtained the diagonal, the side for another square .. .. = 4·8099

7. Both 3·4011 and 4·8099 become units of measure, each being repeated four times, and with their difference, the Pivot, plus or minus, in setting off the heights of the columns.

In this way the pivot is applied 720 times.
And more units can be deduced from these.

On the Division of an English Foot and Yard.

The divisions of a foot in length geometrically is effected first by bisection, then again each half by bisection.

This is analogous to the division of a circle into quarters of 90° each, and also of the division of the length of the upper step of the Parthenon into *four*.

The division of each fourth of a foot into 3 inches, is analogous to the quadrant of a circle being trisectial.

If now we take three-fourths of the foot, or 9 inches, and multiply that by 4, we have 36 inches for the yard; which is analogous to the 36 divisions of the circle of ten degrees each.

Possibly the inch was at first divided into ten.

But the division of an inch by repeated bisections into 8ths and 16ths, may have been adopted as an easier process.

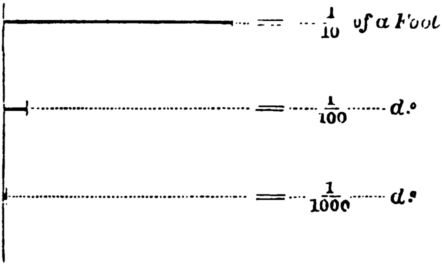
The division of the inch into 10, would have been preferable for calculations, and then $\frac{1}{10}$ of an inch would divide the yard into 360, analogous to the 360° of the circle.

Fig. 17.

The Division of a Foot into Tenths, &c.

This being the scale used by Mr. Penrose, it may assist the comprehension of those not accustomed to use such a measure, as to the precise length of the minute divisions which enter into the measurements and calculations, and which determine with so much accuracy the longer and smaller parts of the Parthenon.

Fig. 17.



Conchoids.

Mr. Penrose has noticed the symmetrical "Conchoids" in his Work.

Although the catenary curves are unquestionably the simplest and easiest of application to such delicate and long curves as the upper step and architrave, &c., both at ends and sides, and also for the entasis of the columns;

Yet the conchoids are more appropriate for representing such lines on drawings, with the utmost approach to accuracy that can be attained.

The conchoids and their reciprocals embrace tens of thousands of useful forms for design and construction. But until known by their appearance and construction they cannot be applied.

A cuspidated conchoidal line has been recently executed as the entasis of the memorial pillar in Ammerdown park, Somersetshire. The line is more than 80 feet long; and the moulds by which the masons prepared the work were within $\frac{1}{16}$ of an inch of the true line in every part.

Mr. Carter Hall, &c.

Soon after I had set out the delicate catenary curves the full length of the upper step, and of the entasis of the columns of the Parthenon, at the Architectural Museum, Mr. Carter Hall presented his copy of the "Principles of Athenian Architecture" to that Institution; without which this work would not have so soon, if ever, appeared.

Although Mr. Penrose has several times in his work named some of my previous efforts and discoveries, it does not appear that it ever occurred to the *forty-two noblemen and gentlemen* whose names are prefixed to that volume, that that work might assist me in accomplishing something more.

Has any of those to whom they presented copies discovered a single law by which so much of the design of the Parthenon was made and constructed?

Amongst all the architects who have gone from all parts to Athens, has any other measured the Parthenon so accurately as Mr. Penrose, or deduced any of the laws of construction therefrom?

If this should be the case it would not be surprising, as when steps of progress have been made, there is evidence that that has been done sometimes nearly at the same time by persons in different parts entirely unknown to each other.

It is now more than *thirty-three years* since I made the discovery of what I have termed "The Septenary system of generating lines."

But, up to this time I have not seen any evidence that this, or any thing approaching it, has been any where made by any other person: or, of much that I have discovered since in connexion with the Septenary system.

Often has the enquiry been made, What is the use of the efforts I have so long been making?

But without much previous research out of the path of the schools and professors, I should not have been prepared to make such discoveries as are now recorded.

Why has not Professor Willis given "A Key to the Proportions of Greek Architecture"?

I returned Mr. Penrose's Work to the Architectural Museum, 18th Feb., 1856.

Suggestions.

If the Committee of the Architectural Museum will give instructions for some of these laws by which the Greeks proceeded to be set out full size, I will render all the assistance I can.

This should also be done at the British Museum, in connexion with the remains of the Parthenon, and which might be placed there to great advantage.

And, also at the Crystal Palace at Sydenham.

Thus thousands and tens of thousands might have the opportunity of making further progress in applying beautiful lines and proportions to designs and constructions.

If the young architect will only *try* to produce so much of the plan and elevation of the Parthenon for which the data is given in this work, and also do the same from Mr. Penrose's or any other work, he will discover a difference.

From the latter, if he has not already done it, he may try at once.

On the principles now described, it will impress them more upon his mind, if done in connexion with setting out more of the work full size at the Architectural Museum.

Other proportions for columns may be obtained from other inscribed and circumscribed figures, and compared with these, thus:

1. The equilateral triangle.
2. The square (applied in the Parthenon).
3. The Pentagon.
4. The Hexagon. &c., &c.

From all distinctly different proportions, for columns, &c. may be obtained.

My suggestions for a "Gallery of Geometrical Models, &c.," was included in the list of the Commissioners for '51 Exhibition. In the first part of this work I submitted that "War" ought not to be an excuse for the commencement of what is so much required. And now that Peace is hoped for, there can be no plea for delay.

Wherever the position of such a Gallery may finally be considered best, the commencement of a Collection, and an arrangement of diagrams, specimens of forms, models, and apparatus, ought not for one moment to be protracted.

These might be commenced in any room, and amongst the numerous buildings in the occupation of Government surely one or more could be found for such purpose. If not, why should not Government take the empty galleries at the Palace at Sydenham, in which to commence and exhibit this branch of science, or any other collections? Why keep even those articles which they may have on hand out of sight, when there is such ample space for displaying so much, unoccupied?

Lastly, that these facts should have the revisal of Mr. Penrose, and any other gentlemen competent to examine them, in the process of setting out details full size, and in extending the farther investigation of the Parthenon until the law for proportioning every other part has been re-discovered.

ADDENDA.

" *Gothic or Classic?* "

Under this head recently in the " Builder," Mr. Tite, M.P. and Mr. G. G. Scott shew clearly how *troublesome* by " minutes " " *copy* " or " *guess* " now, take the place of "Science" as so easily and appropriately applied by the Greeks to determine harmonious forms and proportions.

"Science" however still contains an inexhaustible store of principles for form and proportion for every purpose, and for every material, to which design and construction can be applied—for Buttresses, Pillars, &c., as well as Greek Columns, &c., in endless variety, *if sought for*, and *worked out*, without copying. Are there no young Architects in the Institute who will try?

ERRATA.

Page 7, first line, *for* + *put* ×.

" 10 and 13, fifth line from bottom, *after* 2·81 *read* full height of Capital.

W. Davy & Son, Printers, 8, Gilbert Street, Oxford Street.